GSC Advanced Research and Reviews
eISSN: 2582-4597 CODEN (USA): GARRC2
Cross Ref DOI: 10.30574/gscarr
Journal homepage: https://gsconlinepress.com/journals/gscarr/

(Research Article)

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Influence of nitrogen-potassium fertilizers on plantain banana fruits physicochemical characteristics during ripening

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GSC Advanced Research and Reviews, 2022, 11(02), 008–022

Publication history: Received on 18 February 2022; revised on 30 March 2022; accepted on 01 April 2022

Article DOI: https://doi.org/10.30574/gscarr.2022.11.2.0059

Abstract

This study was undertaken to measure the impact of fertilizers (nitrogen-potassium) on plantain fruits during ripening. Based on nitrogen and potassium content, different doses of fertilizers (T2, T3, T4, T5 and T6) were applied to two hybrid varieties (PITA 3 and FHIA 21) and a traditional variety (CORNE 1) on an experimental split plot plan with a planting density of 2500 plants per hectare. Results showed that total soluble solids (from 0.1° to 1.9 – hybrids and 2.14 – CORNE 1) and moisture content (PITA 3: 67.64 ± 0.06% – 74.63 ± 1.02%; FHIA 21: 67.81 ± 0.89% – 72.19 ± 2.10% and CORNE 1: 61.71 ± 0.23% - 67.78 ± 1.11%) increased significantly during ripening, while firmness (33.93 ± 1.00 N – 1.78 ± 0.76 N), pH (22.90 ± 1.01% - 24.18 ± 2.00%) and hue angle values for peel (27.03% - 31.02%) and pulp (0.05% - 3.66%) decreased considerably. Fruit grown without fertilizer T1 had the lowest moisture (PITA 3: 65.07 ± 1.09% - 68.08 ± 2.00%; FHIA 21: 65.35 ± 3.09% - 69.95 ± 0.09% and CORNE 1: 59.00 ± 1.23% - 65.15 ± 0.67%) content and firmness reducing (72.83 ± 0.24% PITA 3 and 79.49 ± 1.87% CORNE 1). In contrast, PITA 3 (92.14 ± 2.01%) and CORNE 1 (86.84 ± 1.03%) fruits from T4 treatment with high nitrogen content (360 kg/ha) had the highest firmness drop at yellow stage of ripening. Firmness of hybrid PITA 3 and FHIA 21 yellow fruits were twice (3.22 ± 0.03 N; 3.08 ± 0.12 N) smaller than CORNE 1 fruits (7.74 ± 1.02 N). The CORNE 1 fruits were the least humid and the firmer.

Keywords: Nitrogen; Potassium; Fruit characteristics; Ripening; Banana variety

1. Introduction

Among cultivated banana, plantain constitutes a homogeneous group with cultivars whose genome is triploid and bispecific (ABB). Plantain fruits are staple food and important cash crop for many developing countries. It is important for food security [1]. In contrast to dessert bananas, plantain fruits must be cooked before eating and are energy food able to provide to body 120 kcal or 497 kJ per 100 g.

With a production of 1.6 million tons, the plantain crop ranks third in annual food production after yam and cassava in Côte d'Ivoire [2]. It is a means of diversifying and increasing income, due to the external markets that are developing [1]. Unfortunately, the low crop density (1667 plants. ha^{-1} to 2500 plants.ha^{-1}) has long led to low yields [3]. A decade ago, Chaudhuri and Baruah (2010) [4] showed that increasing planting density in pure culture improves yields. Thus, since 2016, the crop density has increased to 2500 plants. ha^{-1} for traditional varieties CORNE 1 and Orishele and hybrids PITA 3 and FHIA 21 [5].

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Moreover, population growth is leading to an ever-increasing demand, which far exceeds supply [6]. As a result, the strong pressure on agricultural land reduces its availability and causes a significant drop in soil fertility and crop yields [7, 8]. To compensate for this state of affairs, chemical fertilizers are used to correct the soil's deficiency in mineral elements and improve crop productivity [9]. To this end, Moughli (2000) [10] showed that plants need essentially and significant quantities of nitrogen (N), phosphorus (P) and potassium (K) to complete their growth cycle.

Among these minerals, nitrogen and potassium are especially recommended for plantain cultivation [11] as opposed to phosphorus requirements [12]. N'Guetta and al. (2016) [5] showed in a recent study that for an intensive crop (2500 plants. ha^{-1}) of plantain (CORNE 1, FHIA 21 and PITA 3), the doses of 240 $kg.ha^{-1}$ (N) and 658 $kg.ha^{-1}$ (K) are recommended. That was opposed to those previously proposed by N'Guessan and al. (1993) [3] witch were 100 $kg.ha^{-1}$ (N) and 240 $kg.ha^{-1}$ (K). According to Loué (1979) [13], beyond the quantities of minerals, it is indispensable to consider nitrogen-potassium interaction for better appreciation of plants response. Indeed, nitrogen contributes to the vegetative development of all aerial parts of the plant [14] while potassium has a great influence on fruit quality attributes and plant yield [15]. However, the physiological functions of nitrogen and potassium in plant production are closely related [16]. Thus, potassium intake may increase the efficiency of nitrogen use or exert a limiting effect. Similarly, higher potassium uptake results in a parallel increase in nitrogen uptake [13, 16]. This indicates that the nitrogen-potassium interaction is the most important interaction with potassium [13].

The objective of this contribution to the improvement of plantain productivity in Côte d'Ivoire is to determine the impact of different doses of nitrogen and potassium on plantain during fruits ripening.

2. Material and Methods

2.1. Vegetal material

The plant material was fruits of 3 varieties of plantain including 2 tetraploid hybrids PITA 3 (AAAB) and FHIA 21 (AAAB) with high yield and tolerant to Black Berry Disease (BBD), and a local variety CORNE 1 (AAB). These fruits were produced at the research station of the National Center for Agronomic Research (CNRA) in Bimbresso.

2.2. Study area

Experimental field was conducted in Bimbresso research station (Anguédédou) at 25 km west of Abidjan with the following geographical coordinates: 5°25' North latitude, 4°08' West longitude and 25 m altitude. The soils in this area, clayeysandy by nature are ferrallitic. Before mineral input, total nitrogen content was 0.11 $g.kg^{-1}$. The CEC and K+ content was respectively 5.34 méq/100g and 0.35 $cmol.kg^{-1}$. The acid soils (pH = 5.31) of the experimental area had 32 $mg.kg^{-1}$ available phosphorus content and 220.75 mg.kg-1 total phosphorus.

2.3. Sampling

Experimental device was in split plot plan with doses of fertilizers as the main factor and plantain varieties as secondary factor. Planting density was 2500 plants per hectare with plants equidistant of 2 m. Each experimental unit or elementary plot of 60 m^2 had 15 useful plants. Plantain variety was composed of three modalities: PITA 3, FHIA 21 and CORNE 1. Fertilization was defined by the doses of nitrogen and potassium to be applied to the plants as a treatment (T). According to N'Guetta and al. (2016) [5], for a density of 2500 plants. ha^{-1}, 240 $kg.ha^{-1}$ of nitrogen and 658 $kg.ha^{-1}$ of potassium (T2) are recommended. Based on this recommendation, 5 doses (T2-T6) were considered and compared to control without fertilizer (T1):

- T1. Without fertilizer (Control)
- T2. 240 kg. ha^{-1} N and 658 $kg.ha^{-1}$ K (Conventional or recommended dose)
- T3. 120 kg. ha^{-1} N and 658 kg. ha^{-1} K
- T4. 360 kg. ha^{-1} N and 658 kg. ha^{-1} K
- T5. 240 kg. ha^{-1} N and 329 kg. ha^{-1} K
- T6. 240 kg. ha^{-1} N and 987 kg. ha^{-1} K

The number of treatments was defined according to factorial plan which was plantain variety (3) × fertilizer doses (6), i.e., 18 treatments. The 18 experimental plots were repeated on 3 blocks on an area of 5184 m^2.

Plantain bunch was harvested when a ripe fruit appeared on its first hand. In the laboratory, fruits from the second and third hands were stored in the open air. Three fruits were collected at each of the seven stages of ripening [17].

2.4. Evaluation of fruit pulp moisture and firmness

Moisture content was determined by oven drying at 105°C for 24 h a known quantity of pulp [18], while the pulp firmness was measured using a manual penetrometer (casse model) on the 2 halves of the fruit and the results were expressed in Newtons (N) [17].

2.5. Evaluation of pulp total soluble solids and pH

At each ripening stage, 15 g of pulp tissues were collected from the medium part of the fruit and grinded within 2 min in an electric blender with 45 mL distilled water. The pulp juice was obtained after filtration using Whatman N°1 paper. A drop of the filtrate was placed on the prism of a refractometer (REF 13, Brix ranges from 0 – 32%, at 20°C) that was finally pointed towards a light source. The refractive index (RI) was expressed in °Brix and represented the total soluble solids of the pulp. The pH of the pulp juice was measured with a bench top pH meter (Inolab, pH level 2).

2.6. Evaluation of peel and pulp colour

Plantain peel colour was measured with a CR-300 Chromameter (Konica Minolta CR series) and described using the CIE L, a, b colour system [37] (Individual values of L* [lightness: 0 (black) to 100 (white)]; a* [greenness to redness] and b* [blueness to yellowness]). The colour measurements were taken at 3 different sections of the midpoint and the peel of the plantain fruits. The hue angle calculated using the Doreen formula [19] was taken as colour value of fruit.

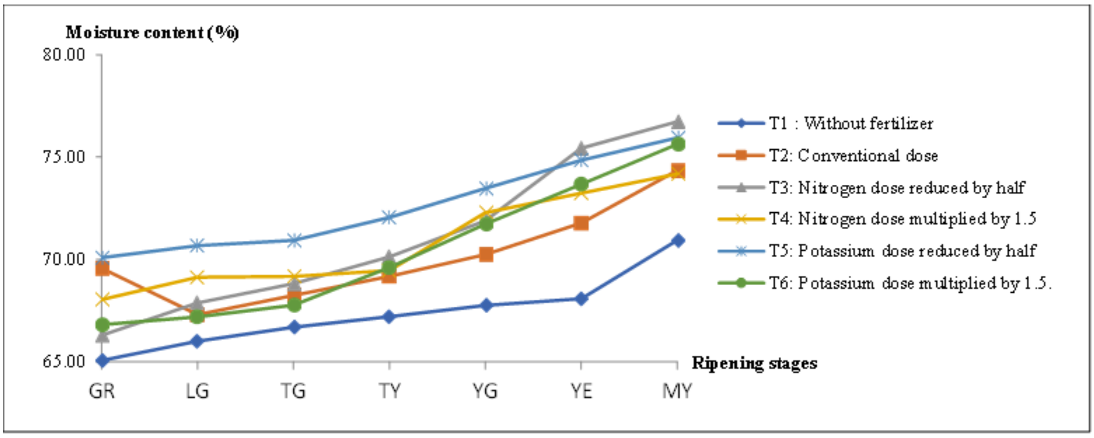
2.7. Statistical analysis

Triplicated data were presented as mean ± standard deviation. And means are been used to make graphics using excel software 2010 version.

3. Results

3.1. Effect of fertilizers on the evolution of pulp moisture during ripening

At the green stage, the moisture of the fruits of the PITA 3 variety ranged from 65.07 ± 0.52% (T1) to 70.08 ± 0.46% (T5) and at the yellow stage from 68.08 ± 0.11% (T1) to 75.43 ± 0.52% (T3). Fruits in treatment T1 had the lowest moisture, followed by fruits in treatment T2. The fruits in treatment T5 had the significantly highest moisture (Figure 1).



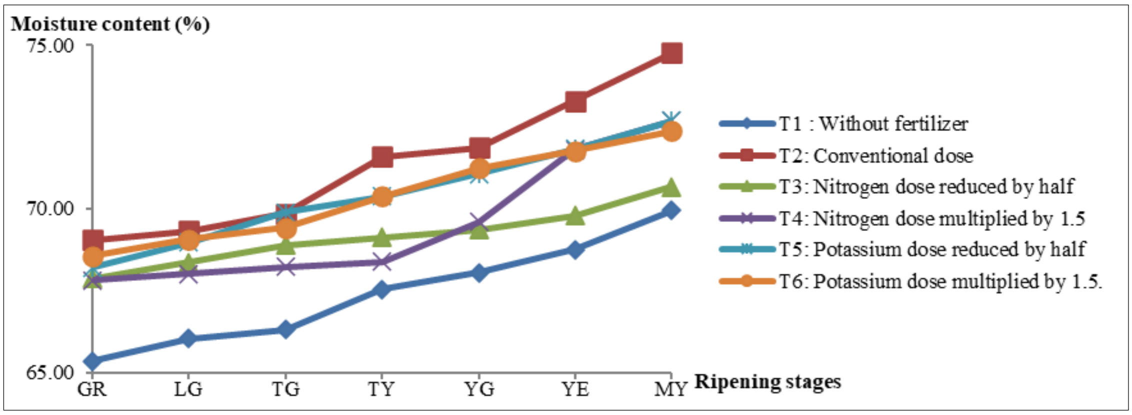
GR: green, LG: light green, TG: turning green, TY: turning yellow, YE: yellow, MY: mottled yellow

Figure 1 Evolution of pulp moisture in PITA 3 fruits during ripening

In FHIA 21 fruits, the moisture at green stage ranged from 65.35 ± 0.43% (T1) to 69.06 ± 0.26% (T2). Fruits from treatment T2 had significantly higher moisture and fruits from zero control T1 had the lowest moisture. At the yellow stage, fruit moisture contents fluctuated between 68.76 ± 0.37% and 73.30 ± 0.46% (Figure 2).

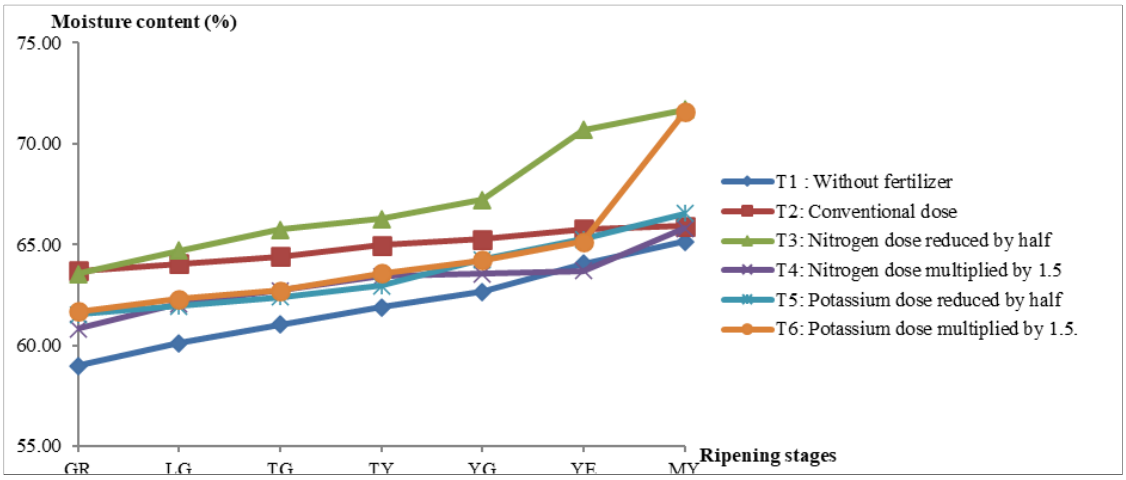
The moisture of the fruits of the variety CORNE 1 (Figure 3) at the green stage was between 59 ± 0.02% (T1) and 63.69 ± 0.13% (T2). At the yellow stage, the moisture ranged from 63.70 ± 0.05% (T4) to 70.70 ± 0.51% (T3). The fruits of the T3 treatment recorded the significantly highest moisture followed by the fruits of the T2 treatment while those of the T1 treatment recorded the significantly lower values.

The variations in moisture from green to yellow stage were 3.01% to 5.35%, 3.41% to 4.24% and 4.70% to 7.01% respectively in PITA 3, FHIA 21 and CORNE 1 fruits. Fruits of the CORNE 1 variety recorded significantly lower moisture than fruits of the hybrids PITA 3 and FHIA 21 during ripening.



GR: green, LG: light green, TG: turning green, TY: turning yellow, YE: yellow, MY: mottled yellow.

Figure 2 Evolution of pulp moisture in FHIA 21 fruits during ripening



GR: green, LG: light green, TG: turning green, TY: turning yellow, YE: yellow, MY: mottled yellow

Figure 3 Evolution of pulp moisture in CORNE 1 fruits during ripening

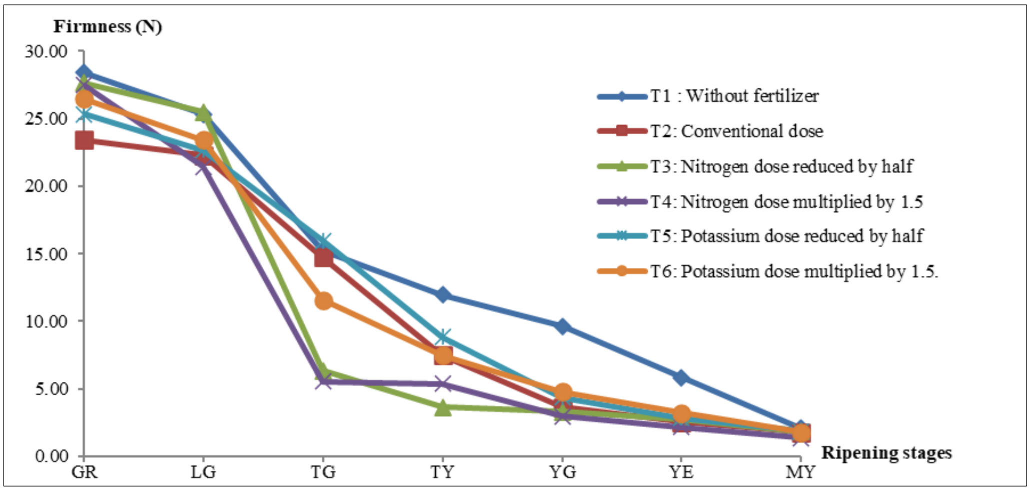
3.2. Effect of fertilizers on the evolution of pulp firmness during ripening

The firmness of PITA 3 fruits at the green stage ranged from 23.45 ± 0.10 N (T2) to 28.43 ± 0.41 N (T1). It decreased during ripening (Figure 4). The reduction in firmness of fruits from treatments T2 and T5 was statistically slower than that of T1 zero control. While fruits from treatments T1, T2 and T5 showed a reduction of 15 N to 16 N from green stage (stage 1) to turning yellow stage (stage 4), fruits from treatments T3 (27.67 ± 0.39 N - 6.33 ± 0.36 N) and T4 (27.47 ± 0.64 N to 5.53 ± 0.16 N) had losses in firmness of 20 N from green stage (stage 1) to turning green stage (stage 3). The drop in firmness in PITA 3 fruit was more drastic with treatments T3 and T4. After the green turning stage, the firmness started to decrease more slowly until the yellow spotted stage where it was between 1.34 ± 0.23 N (T4) and 2.08 ± 0.31 N (T1).

At the green stage, the firmness of FHIA 21 fruit ranged from 20.83 ± 0.35 N (T5) to 25.18 ± 1.24 N (T4) for treated fruits and it was 35.65 ± 0.30 N for T1 zero control fruits (Figure 5). The drop in firmness was very pronounced between the green and yellow turning stages. The reduction in tip penetration force was in the range of 30.63 N (T1) and 16.05 N (T2) to 20.18 N (T4). Thereafter, the reduction in firmness was slower until the spotted yellow stage. Fruit firmness in treatments T2 and T5 decreased significantly more slowly than fruit firmness in treatments T1, T3 and T4. Fruit firmness ranged from 2.62 ± 0.18 N (T3) to 4.55 ± 0.13 N (T2) at the yellow stage and from 0.93 N (T3) to 3.27 ± 0.14 N (T2) at the spotted yellow stage.

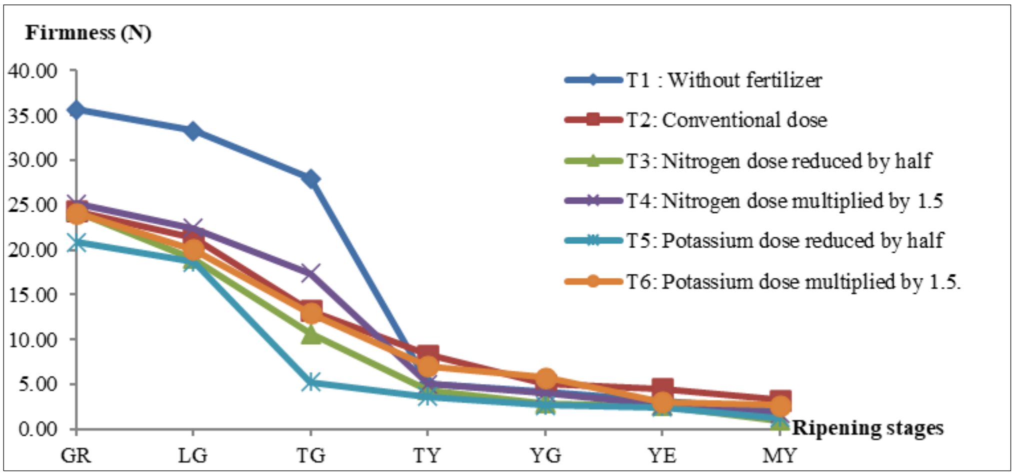
At the green stage, the firmness of CORNE 1 fruits ranged from 31.47 ± 0.98 N (T1) to 42.92 ± 1.46 N (T4) (Figure 6). The firmness values of the T1 (31.47 ± 0.98 N) and T6 (33.93 ± 0.68 N) fruits were significantly lower than those of the T2 recommended treatment (36.53 ± 1.59 N). It decreased significantly between the green and yellow turning stages. The drop in firmness of these fruits during ripening was 34.12 N in fruits from treatment T4 (42.92 ± 1.46 N - 8.80 ± 0.37 N); whereas fruits from treatments T1 (31.47 ± 0.98 N - 17.97 ± 0.33 N) and T6 (33.93 ± 0.68 N - 17.52 ± 0.69 N) recorded losses of 13.52 N and 16.41 N respectively. The rate of fruits firmness degradation was greater in fruit from treatment T4 and lower in fruits from treatments T1 and T6. At the yellow stage, firmness values ranged from 4.85 ± 0.13 N (T2) to 14.08 ± 0.86 N (T6).

The fruit firmness of CORNE 1 variety was higher than those of hybrid varieties PITA 3 and FHIA 21 during ripening. The fall in firmness of the hybrids was twice as fast as in the traditional variety CORNE 1.



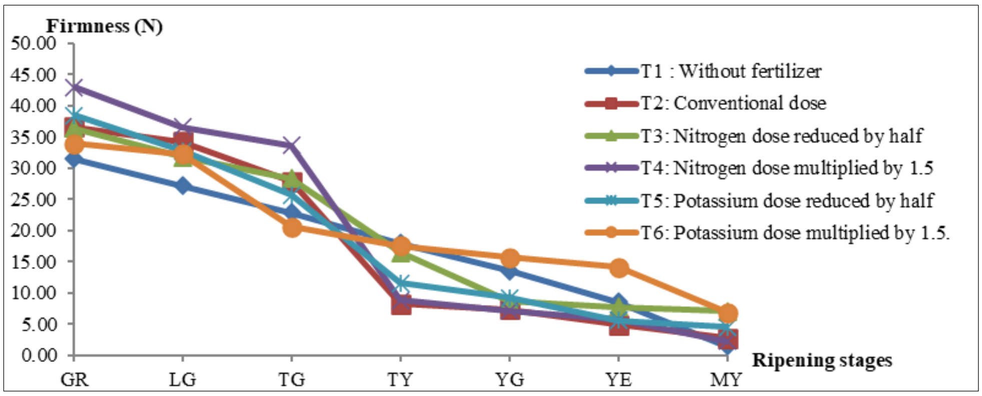
GR: green, LG: light green, TG: turning green, TY: turning yellow, YE: yellow, MY: mottled yellow

Figure 4 Evolution of PITA 3 fruits pulp firmness during ripening



GR: green, LG: light green, TG: turning green, TY: turning yellow, YE: yellow, MY: mottled yellow.

Figure 5 Evolution of FHIA 21 fruits pulp firmness during ripening

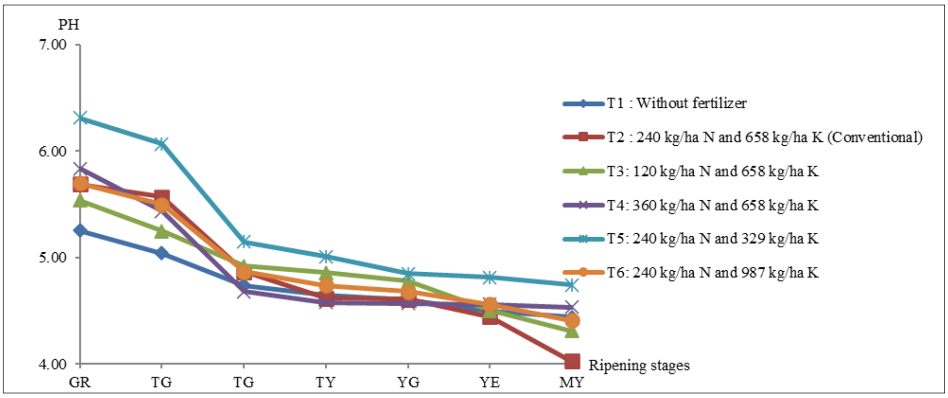


GR: green, LG: light green, TG: turning green, TY: turning yellow, YE: yellow, MY: mottled yellow.

Figure 6 Evolution of CORNE 1 fruits pulp firmness during ripening

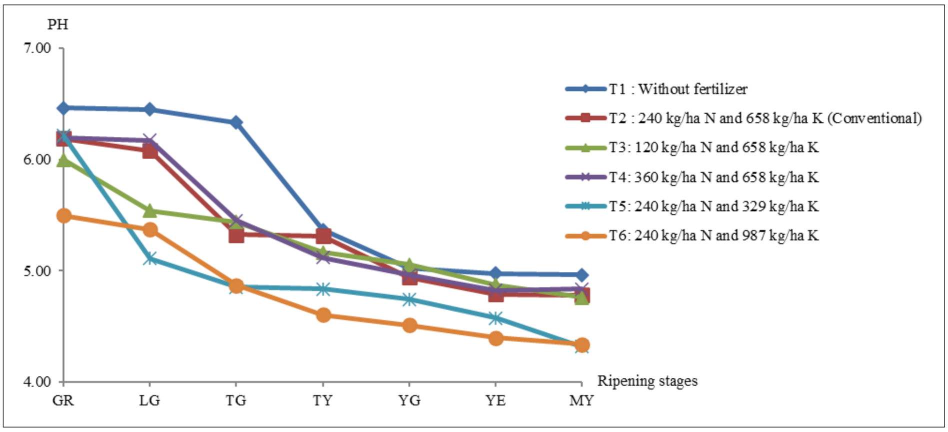
3.3. Effect of fertilizers on the evolution of pulp pH during ripening

The pH of PITA 3 variety fruits at the green stage ranged from 5.25 ± 0.03 (T1) to 6.31 ± 0.01 (T5) (Figure 7). The pH decreased during ripening to 4.49 ± 0.01 (T1) and 4.45 ± 0.01 (T2) at the yellow stage. The pH of the fruits in treatments T3, T5 and T6 were higher than the pH of the fruits in the zero control (T1). Only fruits in treatment T5 had pH values entirely higher than fruits in the recommended treatment. The rate of pH reduction was slower in treatment T1 and faster in treatment T5 with a drop of 1.50 at yellow stage; 2 times the level of drop in treatment T1.



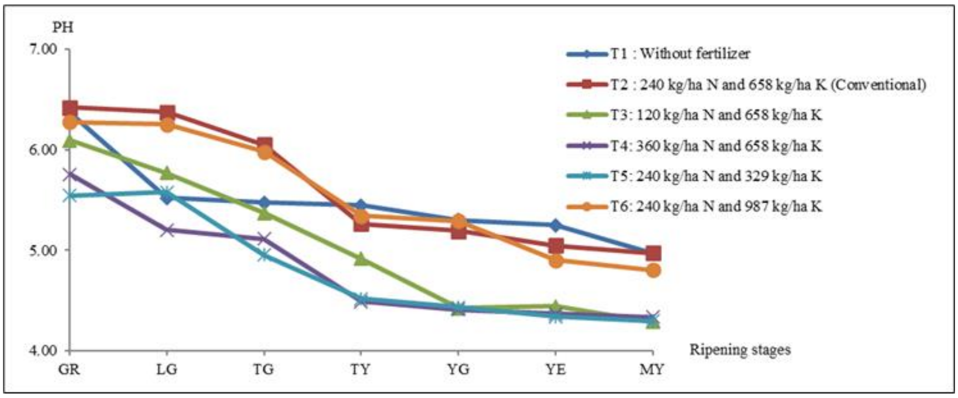
GR: green, LG: light green, TG: turning green, TY: turning yellow, YE: yellow, MY: mottled yellow.

Figure 7 Evolution of PITA 3 fruits pH during ripening



GR: green, LG: light green, TG: turning green, TY: turning yellow, YE: yellow, MY: mottled yellow.

Figure 8 Evolution of FHIA 21 fruits pH during ripening



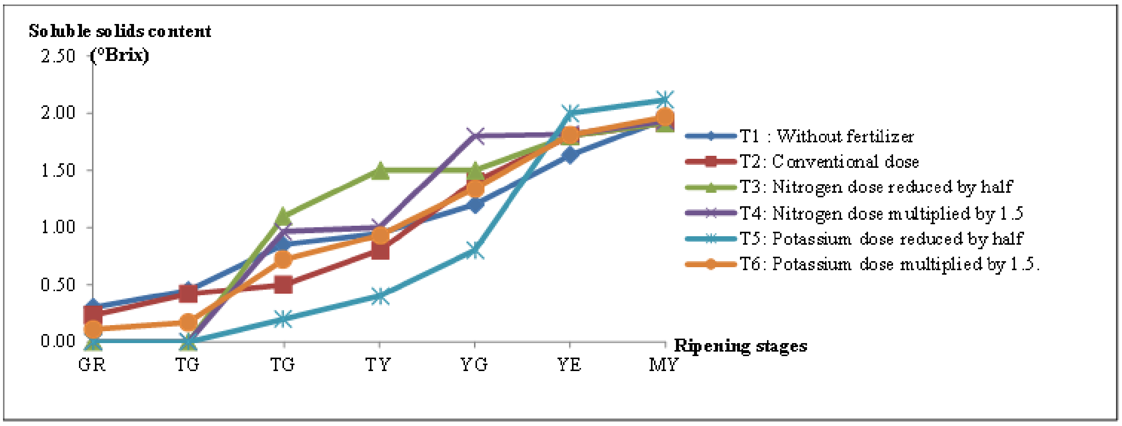
GR: green, LG: light green, TG: turning green, TY: turning yellow, YE: yellow, MY: mottled yellow

Figure 9 Evolution of CORNE 1 fruits pH during ripening

For FHIA 21 fruits, pH values ranged from 5.50 ± 0.03 (T6) to 6.46 ± 0.00 (T1) at green stage. At the yellow stage the pH values varied between 4.40 ± 0.04 (T6) and 4.98 ± 0.00 (T1) (Figure 8). During ripening, fruits from treatment T1 had significantly higher pH values. The pH of the fruits in treatments T5 and T6 were entirely higher than the pH of fruits in the control treatment T2. The rate of acidification was slower in treatments T3 and T6 with reductions of 1.13 and 1.10 respectively and faster in treatment T5 fruits with a reduced pH of 1.90 at the yellow stage.

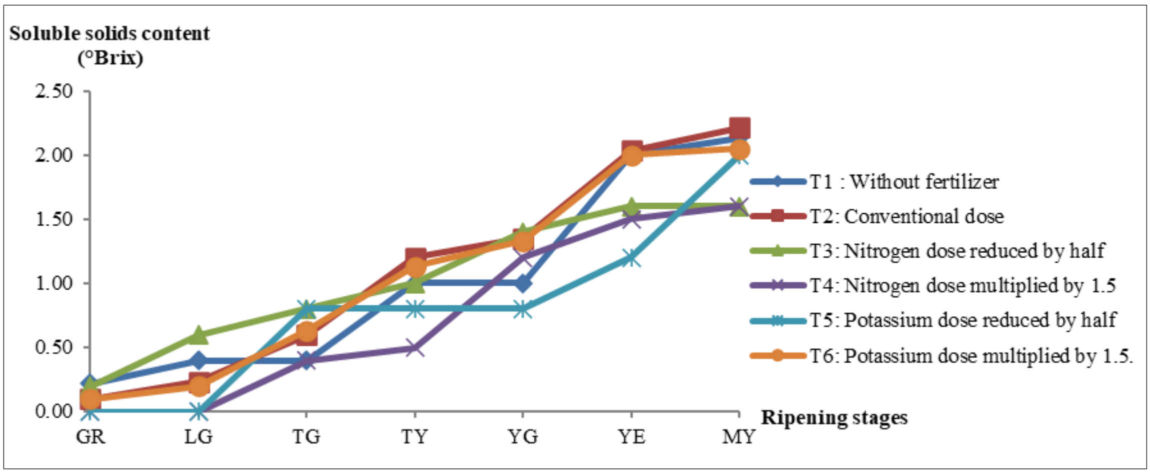
For CORNE 1 variety at the green stage, fruits of treatments T1 (6.36 ± 0.00), T2 (6.42 ± 0.00), T3 (6.09 ± 0.10) and T6 (6.28 ± 0.01) had a pH higher than 6 and those of treatments T4 (5.75 ± 0.00) and T5 (5.54 ± 0.04) were lower than 6 (Figure 9). The progressive acidification of the pulp during ripening was accelerated in the fruits of treatment T3 with a decrease of 1.69 at the yellow stage and slower for the fruits of treatments T4 and T5 with reductions of 1.11 and 1.20 respectively. The pH of fruits from the different treatments was significantly lower than the pH of fruits from the zero control (T1), and then from the recommended control (T2). At the yellow stage, fruits from treatments T1 (5.25 ± 0.00) and T2 (5.05 ± 0.00) had significantly higher pH values than fruits from treatments T3 (4.44 ± 0.02), T4 (4.36 ± 0.00), T5 (4.34 ± 0.01) and T6 (4.90 ± 0.00).

3.4. Effect of fertilizers on the evolution of pulp total soluble solids during ripening



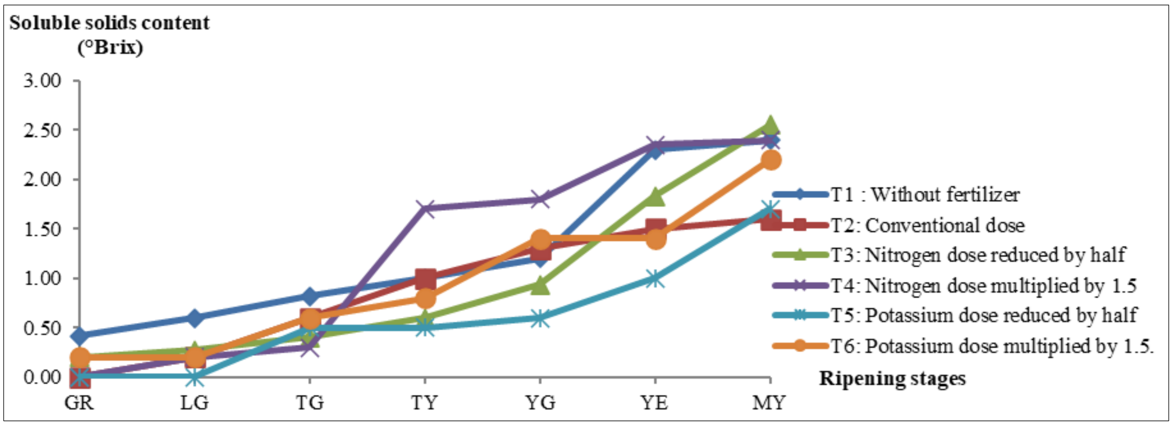
GR: green, LG : light green, TG : turning green, TY : turning yellow, YE : yellow, MY : mottled yellow.

Figure 10 Evolution of total soluble solids in PITA 3 fruits during ripening



GR: green, LG : light green, TG : turning green, TY : turning yellow, YE : yellow, MY : mottled yellow

Figure 11 Evolution of total soluble solids in FHIA 21 fruits during ripening



GR: green, LG : light green, TG : turning green, TY : turning yellow, YE : yellow, MY : mottled yellow.

Figure 12 Evolution of total soluble solids in CORNE 1 fruits during ripening

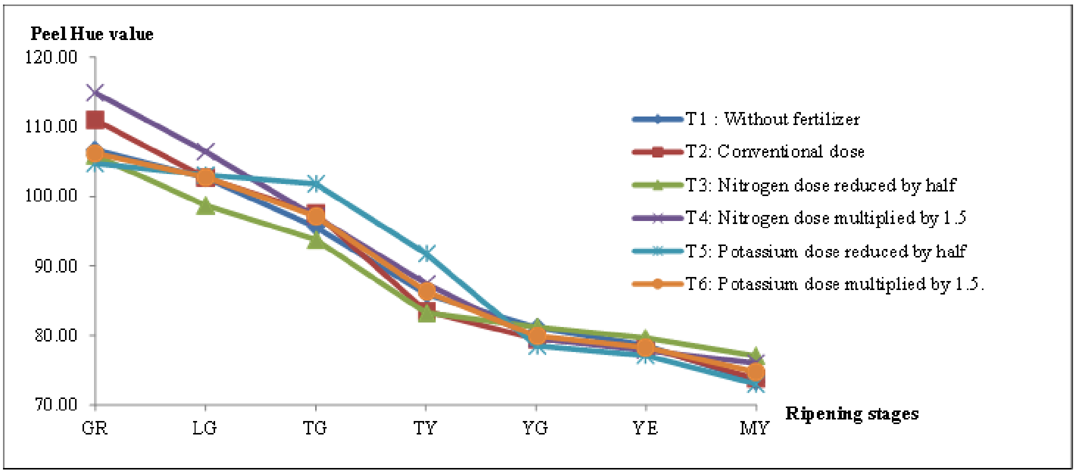
The sugar content of PITA 3 fruits from treatments T3, T4 and T5 was zero at green and light green stages. Fruits from treatment T1 had significantly higher TSS levels (Figure 10). From the green turning stage onwards, sugar levels increased in the fruits. From 0.20 ± 0.01°Brix (T5) to 1.10 ± 0.00°Brix (T3) at the green turning stage, the amount of sugar reached 1.9 ± 0.01°Brix at the spotted yellow stage for all fruits except those from treatment T5 with a Brix level of 2.12 ± 0.02°Brix. The sugar content of the fruits from treatment T5 had statistically lower values until the green-yellow stage and then significantly higher values at the yellow and spotted yellow stages. The sum total of the recorded TSS values showed that the fruits of treatments T3 (7.82°Brix) and T4 (7.52°Brix) were sweeter than the fruits of the zero control (7.33°Brix) and the recommended control (7.07°Brix).

For FHIA 21 variety (Figure 11), fruits of T4 and T5 treatments recorded zero values at the green and light green stages. The fruits of the zero control (0.22 ± 0.01°Brix) had the highest sugar content at the green stage. The increase in sugar content during ripening was variable in the treatments and in the passage of the different stages. At the yellow stage, fruits from treatments T1 (2.00 ± 0.00°Brix), T2 (2.03 ± 0.01°Brix) and T6 (2.00 ± 0.00°Brix) were significantly sweeter and fruits from treatments T4 (1.50 ± 0.00°Brix) and T5 (1.20 ± 0.00°Brix) less sweet. The comparison of the sum of the contents by treatment allowed to distinguish the fruits of the recommended control T2 (7.73°Brix) as the sweetest and the fruits of treatments T3 (7.20°Brix) and T6 (7.45°Brix) significantly sweeter than the fruits of the zero control (7.15°Brix).

With CORNE 1 variety (Figure 12), the fruits of treatments T2, T4 and T5 had zero Brix values at the green stage and also at the light green stage for the fruits from treatment T5. At the yellow stage, fruits from treatments T1 (2.30 ± 0.00°Brix) and T4 (2.35 ± 0.00°Brix) were significantly sweeter and fruits from treatment T5 (1.00± 0.00°Brix) less sweet. The sums of the different contents compared showed that only the fruits of treatment T4 (8.75°Brix) were sweeter than the fruits of the zero control (8.73°Brix) and the fruits of treatment T5 (4.30°Brix) were less sweet than the fruits of recommended treatment T2 (6.20°Brix).

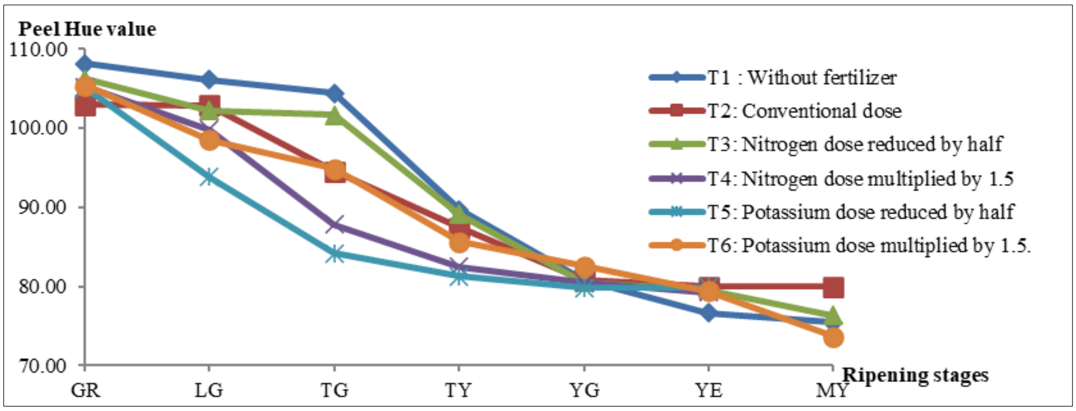
Sugar contents of PITA 3, FHIA 21 and CORNE 1 fruits were statistically equal during ripening.

3.5. Effect of fertilizers on the evolution of peel colour during ripening



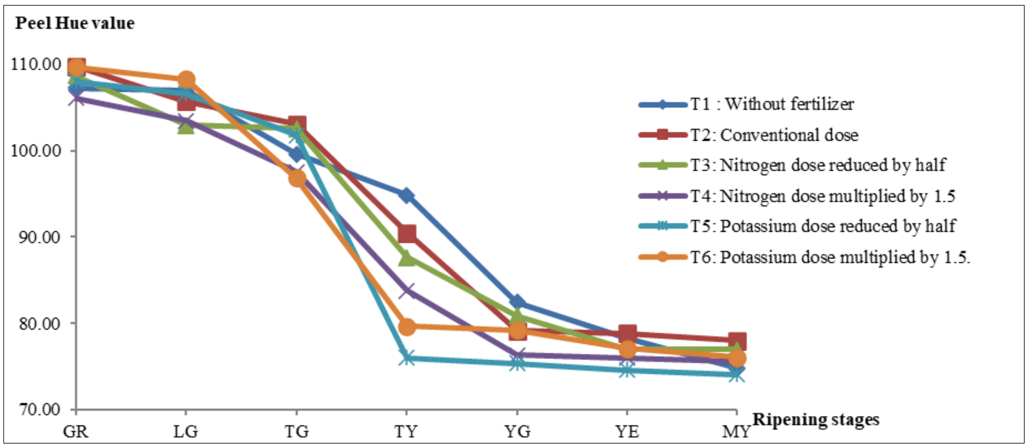
GR: green, LG: light green, TG: turning green, TY: turning yellow, YE: yellow, MY: mottled yellow

Figure 13 Evolution of PITA 3 fruits peel colour during ripening



GR: green, LG: light green, TG: turning green, TY: turning yellow, YE: yellow, MY: mottled yellow.

Figure 14 Evolution of FHIA 21 fruits peel colour during ripening



GR: green, LG: light green, TG: turning green, TY: turning yellow, YE: yellow, MY: mottled yellow

Figure 15 Evolution of CORNE 1 fruits peel colour during ripening

The fruit of PITA 3 had a peel hue angle value (H) between 104.75 ± 1.12° (T5) and 106.70 ± 0.38° (T1) (Figure 13). These values decreased during ripening and at the yellow stage, they ranged from 77.11 ± 0.36° (T5) to 79.62 ± 1.11° (T3). The rate of discoloration was significantly higher in fruits from T4 and T2 treatments and slower in fruits from T3 treatment with reductions of 37.05; 32.67° and 26.27° respectively.

In fruits of FHIA 21 variety, the peel hue values fell within the range 102.95 ± 0.56° (T2) - 108.14 ±0.32° (T1) at the green stage and within the range 76.68 ± 1.01° (T1) - 80.42 ± 0.11 (T4) at the yellow stage (Figure 14). The drop was more pronounced with fruit of T1 treatment with a loss of 31.46°. Fruits in treatment T1 had significantly higher peel hue angle values until the yellow turning stage, and fruits in treatment T4 had significantly higher values than the control T2 except at the yellow spotted stage.

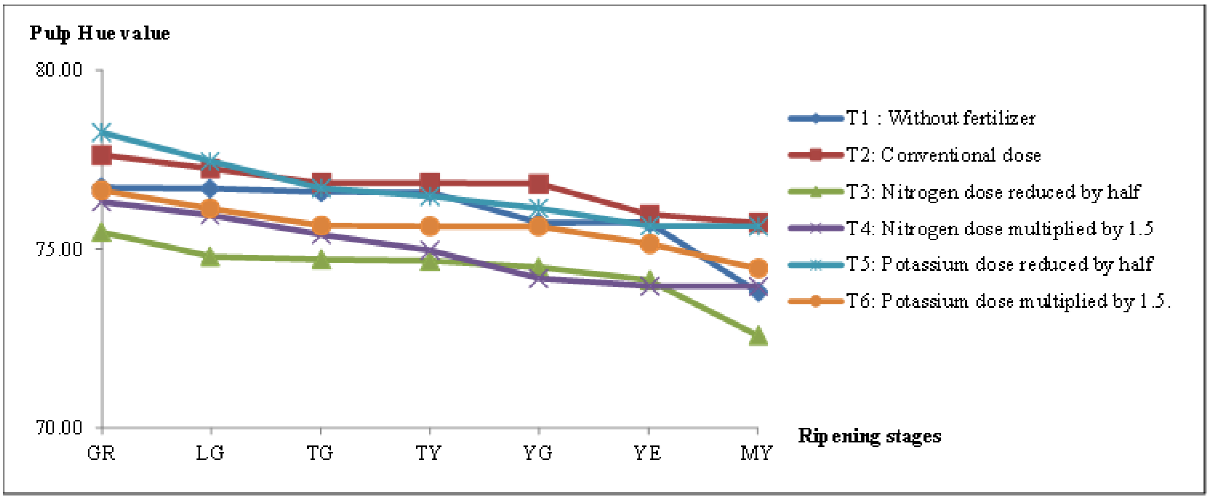
In CORNE 1, peel hue values ranged from 106.12 ± 0.31° (T4) to 109.77 ± 0.03° (T2) at the green stage and from 74.59 ± 0.01° (T5) to 78.87 ± 0.61° (T2) at the yellow stage (Figure 15). The drop in peel hue value was less pronounced in the T1 treatment fruits. The peel hue angle values of fruits from treatment T2 were significantly higher than those of fruits from treatments T3 and T4. Treatment T1 fruit had significantly higher hue peel values than T4 treatment fruit up to the yellow stage and T5 treatment fruit between the turning yellow and spotted yellow stages.

In general, the peel hue value dropped sharply between the green and yellow turning stage and stabilized between the yellow turning and spotted yellow stages.

The peel colours of PITA 3, FHIA 21 and CORNE 1 fruits only differed significantly at the yellow stage, and FHIA 21 fruits (79.31 ± 0.88°) showed a more pronounced yellow coloration than PITA 3 (76.98 ± 1.12°) and CORNE 1 (78.29 ± 0.55°) fruits.

3.6. Effect of fertilizers on the evolution of pulp colour during ripening

In PITA 3, fruits from treatments T2 and T5 had pulps with a significantly greater hue angle than the zero control. The pulps from treatments T3 and T4 had significantly lower values. Pulp hue value decreased during ripening. At the green stage, it ranged from 75.47 ± 0.35° (T3) to 78.26 ± 0.25° (T5) and at the yellow stage it ranged from 73.96 ± 1.12° (T4) to 75.97 ± 0.82° (T2) (Figure 16).



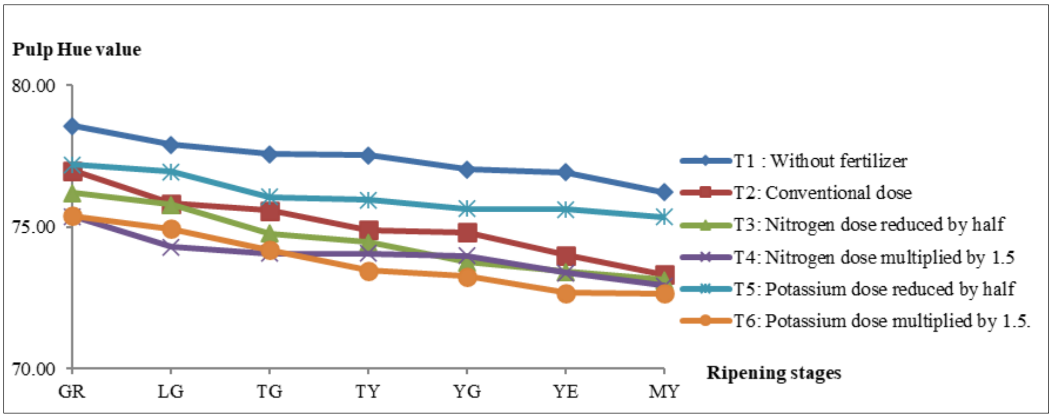
GR: green, LG: light green, TG: turning green, TY: turning yellow, YE: yellow, MY: mottled yellow.

Figure 16 Evolution of pulp hue value in PITA 3 fruits during ripening

In FHIA 21 variety, pulp hue angle values of the fruits from treatment T1 were significantly higher than the hue values of fruits from the different treatments. Only fruits from treatment T5 had higher hue values than the recommended control T2. Pulp hue values of fruits from treatments T3, T4 and T6 were significantly lower. At the green stage, the pulp hue value varied between 75.39 ± 0.06 (T4) and 78.57 ± 0.58 (T1). At the yellow stage, the hue pulp values ranged from 72.68 ± 0.22° (T6) to 76.93 ± 0.24° (T1) (Figure 17).

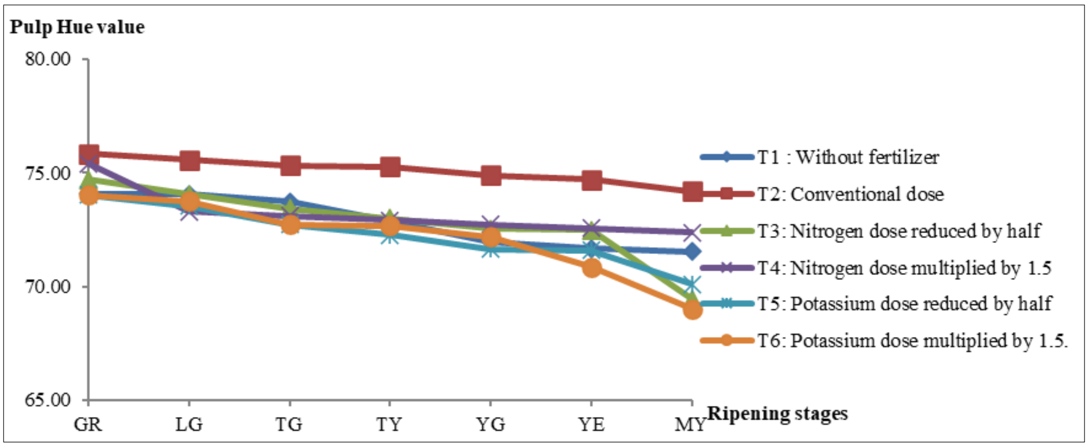
CORNE 1 fruits from treatment T2 recorded the highest pulp hue values. At the green stage, the pulp colour angle ranged from 74.02 ± 0.30° (T5) to 75.84 ± 0.51° (T2) and at the yellow stage, the values ranged from 70.86 ± 0.35° (T5) to 74.69 ± 0.08° (T2). The decrease in pulp hue value during ripening was more pronounced in pulps from T6 treatment and less pronounced in pulps from T2 treatment with respective losses of 3.16 and 1.15 in the transition from green to yellow (Figure 18).

Pulp of CORNE 1 fruits had weaker yellow colorations compared to the hybrid varieties at the yellow-green and yellow stages.



GR: green, LG: light green, TG: turning green, TY: turning yellow, YE: yellow, MY: mottled yellow.

Figure 17 Evolution of pulp hue value in FHIA 21 fruits during ripening



GR: green, LG: light green, TG: turning green, TY: turning yellow, YE: yellow, MY: mottled yellow.

Figure 18 Evolution of pulp hue value in CORNE 1 fruits during ripening

4. Discussion

The moisture content of the fruit increased while the pulps firmness decreased during ripening [20, 21]. Fruit softening during ripening depends on the degradation and depolymerisation of pectic polysaccharides by pectin-hydrolysing enzymes, the hydrolysis of starch to sugars and the osmotic migration of water from the pericarp to the pulp [22, 23]. This was more rapid in fruit from treatments T3 and T4 compared to those of recommended treatment (T2) and treatment with reduced dose potassium (T5). This could be due to the size of the fruit. In fact, To Lou and al. (2021) [24] showed that fruits from T3 and T4 treatments are bigger than those from T5 treatment. The intensity of the reactions would be a function of the nutrient richness of the fruit, resulting in a more rapid softening of larger fruits as mentioned by Newilah and al. (2011) [20].

The more pronounced decrease in firmness in the firmer fruits at green stage could show a tendency towards a lower level of firmness. Mohamed and al. (2018) [25] refer to the final softening stage in mango. The decrease of hue angle (H) of fruit pulp during ripening of PITA 3, FHIA 21 and CORNE 1 varieties reflects the change in colour of the epicarp from dark green to yellow [26]. This change is thought to be due to the destruction of chlorophyll pigments which reveal the carotenoids originally present in the green organs [27]. These external changes are often accompanied by changes in pulp colour [28, 29]. The initially white pulp turns to yellow and the hue values reached 74° to 78° [30].

The content of soluble and reducing sugars in plantain fruits increased during ripening resulting in an increasingly sweet taste during the different stages [20]. This increased number of sugars is due to the hydrolysis of starch into sugars during the ripening process [31, 32]. The fruits of treatments T3 and T4 were the sweetest in PITA 3 variety. In FHIA 21 variety, fruits of treatment T2 were the sweetest. In CORNE 1 variety, fruits of treatment T4 were the sweetest and the fruits of T5 the least sweet. Treatments with a potassium dose equal to 658 kg. ha-1 resulted in the sweetest fruits. Indeed, this mineral plays a role in many physiological and biochemical processes by activating more than 60 enzymes [33, 14]. Starch solubilisation during banana ripening depends on the activities of several enzymes acting simultaneously [34, 35]. Variation in chemical constituents and enzyme activities can be observed depending on the variety and the treatment applied, resulting in a variable sugar content in fruit [36].

The minimum amount of nitrogen required for good growth was 120 kg. ha-1 for the hybrids and 360 kg. ha-1 for traditional CORNE 1 variety. Nitrogen uptake is a function of potassium [37, 38, 39] and the correlation that allows for a good fruit characteristic is a function of variety [40, 41, 42]. Fruits in the T5 treatment were more acidic during ripening compared to those of T2 treatment while fruits in the T2 and T4 treatments recorded the highest pH. The acidification of the pulp during ripening is due to organic acids [43, 44]. The two quantitatively most important acids in plantain are citric acid and malic acid. And, potassium supplied to the plant in the form of fertiliser, plays a major role in malate accumulation [45, 46, 47]. However, the increase in acidity is mainly related to the concentration of citric acid. The higher acidity in fruit from the half-dose potassium treatment (T5) could be explained by a failure to accumulate malic acid in favor of citric acid [48, 49]. Organic acids play an important role in producing a balance between sugars and acids that gives the fruit a pleasant flavor as it ripens.

Fruits from the different treatments showed colour variation during ripening. This difference observed would depend on the carotene content of the fruit from the different treatments [50]. Thus, the pulp of plantain fruits from treatments T2, T3 and T4, which are more colored , would be richer in vitamin A and the pulp of fruits from treatment T5 would be less rich [51]. The pulp of the CORNE 1 fruits had lower H values compared to the hybrid varieties. This observation is related by Adeniji and al. 2006 [52] that different plantain varieties may have differences in colouring. According to Tourjee and al. (1998) [53], the level of carotene can vary from one plantain variety to another depending on the genotypic difference in pigment composition.

5. Conclusion

The moisture content, firmness, pH, soluble solids content and hue value of plantain fruits of the varieties PITA 3, FHIA 21 and CORNE 1 were evaluated during ripening. It was found that the moisture content and soluble solids content of the pulp increased while the firmness, pH and hue angle values decreased.

Fruits from the treatment without fertilizer (T1) had lower moisture content and their firmness decreased more slowly during ripening while the fall in firmness of fruits from the T4 treatment (high nitrogen dose) was the fastest. The firmness of the PITA 3 and FHIA 21 hybrids dropped twice as fast as that of the traditional variety CORNE 1. The soluble solids content of the green fruits was not always zero and the fruits of treatments T2, T3 and T4 were the sweetest. The fruit in treatment T5 acidified more quickly in the hybrid varieties and more slowly in the traditional variety. The colour of the peel and pulp of the fruits tended towards yellow and the PITA 3 and FHIA 21 fruits were more coloured than the CORNE 1 fruits at the yellow and yellow-green stages.

Compliance with ethical standards

Acknowledgments

Thanks to the strategic support project for scientific research (PASRES) for the financial contribution in the implementation of this project.

Disclosure of conflict of interest

The authors declare no conflict of interest.

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